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(54) Methods of operating optical disk apparatus.

(57) Defective sectors on an optical disk 31 are identified during initial format, listed on a primary defect list (PDL) and eliminated as sectors that might possibly be reclaimed at a later date. Those sectors which are identified as defective during use of the disk are listed separately from those found defective at initial format in a secondary defect list (SDL). When excessive spare sector usage has occurred, a cleaning operation is called for. After the cleaning operation, those sectors in the SDL are surface analysed to determine whether they are now good. Further, those defective sectors in the SDL adjacent to sectors in the PDL found initially defective are eliminated as reclamation possibilities.

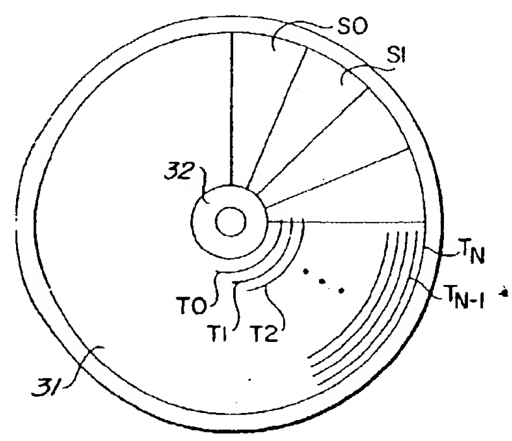

FIG. 3

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This invention relates to methods of operating optical disk apparatus.

Standard optical disks may be formatted with several thousand spare sectors per surface. The purpose of the spare sectors is to provide locations for recording data when defects in the media or debris on the media create the inability to read and write data. In optical disk technology the marks that are placed on a disk when data is written may be only one micron in size, therefore a small defect or a dust particle on the disk can introduce an error when reading or writing the data. Defects in optical disks are generally of two types. One type is within the structure of the disk itself while a second type is the result of dust contamination on the surface of the optical disk. Magneto-optical (MO) disks are more subject to manufacturing defects (that is, a defect within the structure of the disk), than many other types of media as the MO disks are produced with reactive materials such as terbium, iron and cobalt. If any moisture or oxygen reaches the active layer, a defect can result. Such defects may occur during the manufacturing process but they may also arise later during use of the disk.

A defect in reactive material tends to grow during the course of time. The active layers in an MO disk are covered with transparent plastics material designed to be impermeable to oxygen and moisture. If, however, oxygen and moisture reach the active layer, a defect may result and may grow. Consequently, if a defect is initially present in the active layer such that one bit of data in one sector is affected, over a period of time that defect may grow to affect additional bits of data in that sector or adjacent sectors.

The second type of defect creating problems in reading data from and writing data to an optical disk is contamination due to dust or debris. When a particle of dust lights upon the surface of a disk and if the particle is large enough, the laser beam is diffused or blocked by the dust particle and consequently the disk is not written or read at that particular location. Defects created by a dust particle generally do not grow in size, but the defect may move across the surface in the course of time as the dust particle moves.

The result of a defect on a disk is the same whether it be a defect in the reactive material or whether it be due to dust. An optical disk system cannot know what is causing the defect, only that an error exists. The error may make it impossible to correct data that is written on the disk or make it more difficult to correct the data through error correction codes. It may become necessary for the data to be moved to a spare area or sector. If the problem is caused by dust, it may be that the spare area is also contaminated by dust and thus it becomes necessary to move the data to still another spare area. Contamination due to dust can use up spare areas rapidly.

US -A- 4,506,362 relates to dynamic RAM memory wherein if an error in data is found and corrected utilising error correcting codes, the data is then rewritten back to the same RAM storage location. If the error repeats itself, it is assumed that a hard error is present within the apparatus. Dynamic RAMS are subject to soft errors, for example, from the bombardment of the RAM by alpha particles and therefore this technique is designed to distinguish hard errors from soft errors.

US -A- 4,916,703 also relates to distinguishing hard errors from soft errors in RAM storage.

US -A- 4,216,541 relates to an error recovery technique in a bubble memory where data is periodically read and errors are detected and corrected. Once corrected the coded data is rewritten back into the memory.

US -A- 4,926,408 relates to optical disk apparatus containing two heads, one for reading and one for writing. Defects are detected during the formatting operation and sectors with defects are then eliminated from all further reference.

US -A- 4,434,487 relates to a three layer defect management system in a mass storage disk wherein defective sectors are replaced by spare sectors.

US -A- 4,949,326 relates to optical disks and teaches a defect management system for optical disks wherein defective sectors are replaced by spare sectors.

The present invention is based upon a recognition that defects on optical disks are of two types, that is they may be a result of a defect in the reactive material or they can be defects which are a result of contamination, and that whilst defects in the reactive material may not be removed by cleaning, defects due to dust may be eliminated by cleaning the disk.

This invention provides a method of distinguishing errors caused by dust from errors caused by defects within the media and provides for reclaiming sectors after cleaning the disk. This is accomplished by noting all defective sectors found during the initial format and eliminating them as reclamation possibilities. Further, any defective sectors after format time adjacent to those sectors found defective at format time can also be eliminated as reclamation possibilities. Thereafter, during use of the optical disk, once a threshold of spare sector consumption is met, the host is notified that spares are becoming scarce and a request is made for a disk cleaning operation. Once cleaned, those sectors which have been identified as potentially reclaimable are then reformatted to determine whether they are now usable. Those sectors identified as reusable are then reclaimed according to one of the three methods: 1) the reclaimed sectors are defined as additional spares; 2) data originally intended for the reclaimed area but written to a spare area are moved back to the reclaimed area in order to free the spare area; and 3) the reclaimed area is restored to the user area for future write operations.

Thus, the invention provides for the detection of

excessive spare sector consumption due to contamination from dust and recovering of the good sectors after the disk is cleaned.

The scope of the invention is defined by the appended claims; and how it can be carried into effect is particularly described hereinafter with reference to the accompanying drawing in which:-

FIG. 1 is a block diagram of a typical system attachment controller for an optical disk drive using the present invention;

FIG. 2 shows a typical optical disk;

FIG. 3 is a schematic showing of the optical disk of FIG. 2 with tracks and sectors;

FIGS. 4A and 4B are diagrammatic layouts of tracks and sectors with defects;

FIG. 5 is a block diagram of a procedure for setting a threshold beyond which the number of remaining unused spare sectors is indicated as small;

FIG. 6 is a block diagram of a surface analysis procedure for identifying defective sectors through a format operation;

FIG. 7 is a block diagram of a procedure for setting up a list of defective sectors upon the initial disk format;

FIG. 8 is a block diagram of a procedure for determining the percentage of defective sectors for comparison with a threshold;

FIG. 9A is a block diagram of a procedure for determining defective sectors during use of the optical disk;

FIG. 9B is a block diagram of a cleaning process if the number of defective sectors exceeds the threshold;

FIG. 9C is a block diagram of a procedure for determining whether previously defective sectors are reusable after a cleaning operation; and

FIG. 9D illustrates three options for reclaiming the sectors identified as reusable.

A controller 10 (FIG. 1) for a peripheral device in the form of an optical disk drive 23, is connected to a host processor 11 over bus 12. Controller 10 includes target interface logic 13, an optical disk controller 14 and a microprocessor 15. Read only memory (ROM) 16 and random access memory (RAM) 17 are associated with the microprocessor 15. A run length limited (RLL) circuit 18 passes data to and from the drive 23. A buffer 19 provides storage for data and an error correcting code (ECC) logic circuit 20 provides corrections to the data contained in buffer 19. An optical disk 24 may be loaded into drive 23 for writing and reading data to and from the disk.

Microprocessor 15 is the system manager for the controller. It controls the optical disk controller 14 and the drive interface 25. It interprets the commands and monitors the ECC logic through the optical disk controller. The optical disk controller 14 controls the ECC encoding/decoding and the data buffering process. ROM 16 provides for local control storage for the microprocessor 15 while RAM 17 provides working storage to the microprocessor 15. The target interface logic 13 receives commands and data from the host processor over bus 12.

The optical disk for use in the disk drive controlled by the controller 10 may take the form of a cartridge 30 (FIG. 2) containing an optical disk 31 mounted on a hub 32. A shutter door 33 on the cartridge (shown in an open position so as to reveal the disk 31) may be moved to a closed position, so that dust does not have access to the disk. The cartridge must be open for a read/write head to access data on the disk 31, at which time dust may contaminate the surface of the disk.

Tracks and sectors (FIG. 3) are schematically laid out on the optical disk 31. Track zero T0 is the innermost track on disk 31 and is located close to disk hub 32. Tracks proceed from the innermost location to an outermost track Tn. Tracks may be concentric to each other, but in optical disk technology it is common to provide tracks in a continuous spiral. The disk is logically divided into sectors, such as sector zero S0, and sector one S1. It is common practice to provide seventeen equal sectors around the periphery of a disk. Marks written or read on the disk are typically about one micron in size with a minimum space between marks of about 1 micron. There are typically thousands of marks in a sector along each track. In the diagrammatic layout of some tracks in FIG. 4A, there is a defect 40 in sector S2 on track T1, and another defect 41 in sector 4 or track T2. These defects may be large enough to prevent accurate data storage and retrieval within these locations. If so, data on these sectors, or data intended for these sectors, are moved to a spare sector.

In the same layout in FIG. 4B, is illustrated what may happen to the two defects over the course of time. The defect 40 is no longer in sector S2 on track T1, but has moved to sector S2 on track T3. Such a moving defect is due to a dust particle moving across the surface of the disk. The defect 41 in sector S4 on track T2, is a small defect and may be too small to cause the loss of any data at the time of initial format. However the defect 41 has grown in size over the course of time to create a problem in sectors S4 on adjacent tracks T1 and T3. Growth of defect 41 is typical of defects in the reactive layer of the disk. As optical disks are used for mass storage they are often expected to last for many years. Such a long length of time creates ample opportunity for the growth of defect 41.

The present invention is to identify and distinguish between sectors that are contaminated by dust and sectors that are affected by reactive defects. To make that determination, defects are noted when the disk is inserted for the first time into a drive and formatted. In the formatting operation, each and every

sector is written and read and thus it can be ascertained at that initial load which sectors are defective. It is assumed that these defective sectors are due to defects in the reactive material rather than dust as the disk is sealed prior to first use. The expectation is that these defects will probably grow over a period of years. Such growth occurs in all directions, that is, a defect will spread along the same track from bit position to bit position, and will also spread out to sectors on adjacent tracks.

As a disk is used over a significant period of time, the number of defective sectors may increase significantly and when a specific threshold is reached, a request can be made for the user to clean the disk. If the disk is installed in a library, the cleaning may be done automatically. After the disk is cleaned, it is then tested to determine if those sectors which were not defective at the initial format and are not adjacent to sectors which were defective at initial format are now testing good. Testing is accomplished by reformatting such sectors.

In a standard disk structure, the Disk Management Area (DMA) is replicated four times, twice in tracks 0, 1, and 2, and twice more in tracks N-2, N-1, and N, where N is the last track in the user zone. Each DMA contains a first sector with a Disk Definition Structure (DDS) and an area containing the Primary Defect List (PDL) and the Secondary Defect List (SDL). The second sector of the DMA is the first sector of the PDL. The length of the PDL is determined by the number of entries in it. The SDL begins in the sector following the last sector of the PDL, and its length is also determined by the number of entries in it. The start address of the PDL and SDL within each DMA is found in the DDS for that DMA.

During the formatting process defective sectors are found and alternate sectors are assigned from the list of spare sectors. The defective sector and replacement sector addresses are stored in the PDL area of the DMA structure in ascending order of sector addresses. It is assumed that prior to the original formatting of a disk the cartridge has been sealed and therefore there has been no dust accumulation.

The addresses of defective sector locations encountered during use are stored in the SDL area in the DMA structure together with the address of their respective associated replacement sectors. Again the defective sector data is stored in ascending order of sector addresses.

Any new errors that occur after format time in areas not associated physically with the errors found at initial format are potentially errors caused by dust particles.

When a disk is loaded into a drive the DMA structure is loaded into RAM. At this point the controller can tally the defective sectors. When a threshold of spare sectors have been used, for example, when 70% of the spare sectors have been used, an error message is generated and sent to the host. The host then sends a "Request Sense" command to the drive and the sense data shows the percent of spares used. If the drive has recognised that a majority of the errors are not associated physically with the errors found at format time it can be concluded that dust is the problem and a request can be issued that the disk be cleaned.

After the disk is cleaned it is inserted into the drive to determine if some of the previously detected bad sectors are now good. This is accomplished by having the host send a "Format" command to the drive with a "Reclaimed Defective Sector" bit on. Only those sectors which were not defective at format time and were not adjacent to defective sectors at format time are reformatted. After reformatting and performing the surface analysis, those sectors which are now good are reclaimed.

There are three techniques for reclaiming the sectors. One is to consider the reclaimed sectors as new spares, the second is to move customer data from the spare area back to the original location on the disk, and the third is to restore the reclaimed sector to the user area for future write operations.

Defining the newly reclaimed sectors as additional spares eliminates the need to move customer data, thereby saving time. This method also fits those applications requiring high data integrity.

Moving data back to the user area from the spare area requires a manipulation of the user data and the SDL sector information. However, this technique is advantageous for applications requiring high performance as the data will now be found at the original location where it was originally intended to be stored.

The third method, restoring the original sector to the user area for future write operations requires the sending of a "Post Cleaning Processing" bit to the drive via a Mode Select command. The drive controller uses the previously declared defective sector on a subsequent write operation. If successful, the drive controller takes the sector out of the defective sector list and frees the spare assigned to this sector. If the write was not successful, the drive continues to use the previously assigned spare sector and the SDL sector is marked to bypass the reclaim attempts on that defective sector on subsequent write operations. This method is advantageous for applications where files are being updated frequently.

There may be several drives with associated controllers 10 connected on bus 12. Each of the connected drives is initialised to provide a defect threshold. At step 100 (FIG. 5), the host issues a mode select command to the device in order to set the defect threshold. At step 101, a query is made as to whether all the devices in the system have had a threshold set and, if not, step 100 is repeated until all devices in the system have been set.

In the original formatting process for a new disk

a surface analysis procedure is used. At step 110 (FIG. 6), the format command is received from the host and at step 111 a variable m is set equal to the number of sectors per disk side. At step 112, all the sectors on a disk side are erased and, at step 113, all the sectors are written with a specific pattern. At step 114, a variable n is set equal to zero and, at step 115, sector zero is read. At step 116, the query is answered as to whether the pattern data which was written to sector zero, had been read back correctly. If it had, then the variable n is set equal to n + 1 at step 117 and at step 118 the query is asked as to whether all sectors have been read. If not, a return is made to read the next sector at step 115, in order to determine whether the next sector contains a defect. When a defective sector is found at step 116, the address of that sector is stored in RAM at step 119 before a return is made to steps 117 and 118 to inspect the next sector. Once the patterns that have been written to all the sectors have been inspected, the surface analysis is complete.

The next step for preparing the new disk is to write the disk management area (DMA). At step 120 (FIG. 7), the DMA 1 area is erased and the DDS sector is written at step 121. Next at steps 122 and 123 the defective sector addresses (determined and stored at steps 116 and 119), are read out of RAM and written into the PDL area. The DMA data is verified at step 124 and steps 120 to 124 repeated for DMA areas 2, 3, and 4.

In the procedure for determining the number of defective sectors as a percentage of spare sectors, at step 130 (FIG. 8), the cartridge is inserted into the drive and, at step 131, the DMA data is loaded into RAM. At step 132, an inspection is made of the error count in the secondary defect list (SDL) and, at step 132A, that error count is added to the number of defective sectors in the PDL. At step 133, that total error count is divided by the total number of spare sectors available on that particular disk. For example, the number of spare sectors may be two thousand and forty eight. The result of that calculation is stored in RAM at step 134.

In the procedure for detecting a defective sector, at step 140 (FIG. 9A), it is determined whether a write command has been received. If so, the sector is written at step 141 and verified at step 142. If, at step 143, the sector is found to meet the quality requirements for writing the data, a return is made to await the next read or write command. However, if, at step 143, the quality threshold is not met, then a branch is made to step 144 to allocate a spare sector to the defective sector and to write the data in the spare sector. If, at step 140, it is determined that a write command has not been received, at step 148, it is determined whether the command is a read command. If it is, the sectors are read at step 149 and, at step 143, it is determined whether the sector meets the quality requirements for a read command. Generally these requirements are more lenient than they are for a write command. If, however, the quality requirements are exceeded, a branch is made to step 144 and the data is reallocated to the spare sectors. Thereafter, the secondary defect list (SDL) is updated at step 145 and the percentage of defective sectors is updated at step 146. It is then determined, in step 147, whether the percentage of defective sectors is now greater than an allowable threshold. If it is not, a return is made to await the next read or write command. If the threshold is exceeded, a branch is made to the next procedure to provide a notice for activating the disk cleaning process.

It should be noted that at step 143 after the sector had been written it was necessary to determine whether the written sector met a quality requirement of the system. A quality threshold will depend on the number of defects allowed in a sector before declaring the sector defective. The number of defects allowed is dependent upon the error correcting code capability of the system. Generally the quality threshold of a write command will be set at a higher level than that for a read command. That is to say fewer defects are permitted upon writing than upon reading.

The disk cleaning process is started at step 150 (FIG. 9B) by an error message posted to the host that the threshold has been exceeded and, at step 151, the host schedules a cleaning process. At step 152, the request for the cleaning process is issued which can be accomplished by the operator cleaning the disk manually, that is, retrieving it from the drive and placing it in a cleaning station. The process may be done automatically if the disk drives are part of a library containing a cleaning station. In any event, after the disk is cleaned and reinserted in the drive, at steps 153 and 154, a branch is made to a sector reclaiming process.

This sector reclaiming process starts at step 160 (FIG. 9C) when the host sends a format command with an activated reclamation bit to the drive. At step 161, the defect data in the primary defect list (PDL) and the secondary defect list (SDL) are moved to RAM if not already there. At step 162, the next defective sector, in this case the first defective sector in the PDL, track T, sector S is read and if, in step 163, a defective sector is found, the variable N is set equal to T + 1, at step 164. The succeeding steps determine whether there is an address in the SDL adjacent to track T and sector S. To do that, it is determined at step 165, whether the address N,S is in the SDL. If that address is present in the SDL, it is eliminated as a sector which can be reclaimed at step 166. At step 167, the variable N is set equal to N + 1 and the process repeats until all adjacent defective sectors have been eliminated as reclaimable possibilities.

If the determination at step 165 is negative (the address N,S is not in the SDL) a branch is made to

step 168 where the variable N is set equal to T - 1. At step 169, it is determined whether the address N,S is in the SDL. If it is, that address is eliminated as a reclamation possibility at step 170 and, at step 171, N is set equal to N - 1 and the process repeats. All adjacent defective sectors found in the SDL are ultimately eliminated and a branch is made back to step 162 to determine the location of the next defective sector in the PDL and determine whether the SDL has sectors adjacent to that next PDL sector.

Eventually, the PDL list is exhausted as found at step 163 causing a branch to step 180 to determine the next sector that is left in the modified SDL list resident in RAM. If there is none, then no reclaimable sector has been found and the process ends. If one or more sectors remain in the modified SDL list, they have been identified as potentially reclaimable sectors. The first sector is surface analysed at step 181 by writing a pattern on the sector and then reading it back at step 182 to determine whether the sector is now good. If the sector is good, it is placed in a list of reusable sectors at step 183 and the modified SDL list is inspected at step 180 to find the next sector to analyse. However, if at step 182 the sector is found still defective that sector is left in the SDL list at step 182A and the next sector to analyse is identified at step 180. The process then repeats.

When the modified SDL list is exhausted as found at step 180, the list of reusable sectors is inspected at step 184. If no sectors are identified, the process ends, otherwise a branch is made to reclaim the identified reusable sectors according to a chosen option.

In the first option D1 (FIG. 9D), at step 190, the sectors which have been declared reusable are deleted from the SDL and added to the spare sector list or area in order that they can be made available for use by the defective sector replacement algorithm.

In the second option D2, at step 191, data is moved from the designated spare sector and written to the newly identified reusable sector. The sector is verified at step 191A and if found good in step 191B, the writing operation is successful and, at step 192, the SDL table is updated and the spare sector previously allocated to the reclaimed sector is made available as a spare sector. If unsuccessful, the SDL remains unchanged.

In the third option D3, at step 193, the host sends a post clean bit to the drive via a mode select command. This marks the sector for reclaim and the drive controller uses the newly reclaimed sector to update data in the assigned spare sector on a subsequent write operation at step 194. The sector is verified at step 194A and if found good in step 194B the write operation is successful and, at step 195 the sector is taken out of the SDL and the spare, previously assigned to that sector, is freed. If unsuccessful, the updated data is written at step 196 to the assigned spare sector and the reclaim bit is turned off. The SDL is not changed.

In the case where there are relatively few total sectors on the optical disk, there may be no practical need to inspect the PDL and eliminate SDL sectors adjacent to those in the PDL. In such case, after moving the SDL to the RAM in step 161 (FIG. 9C), a branch may be made directly to step 180 to surface analyse all sectors in the SDL.

This invention can also be used for write once disks to alert the user that excessive spare sectors are being consumed. This can occur if the disk becomes dusty during use, causing sectors in the user area and the spare area to become contaminated. In the write-once case, it is not possible to reclaim defective areas, but it is desirable to alert the user to clean the disk to avoid excessive sector use. This is accomplished through use of the procedures set forth in Figures 5, 8, 9A, and 9B only, because the procedures of Figs. 6 and 7 are inapplicable to write-once, as are also the reclaim procedures of Figs. 9C and 9D.

The mode select command is used in step 100 (FIG. 5) to set a desired threshold for the write-once disk. That threshold may be significantly different from a desired threshold set for rewriteable disks, as it is not possible to reclaim write-once sectors after they have been written.

In the defective sector percentage determination procedure (FIG. 8), the count of defective sectors is divided by the total number of spare sectors in step 133 and stored at step 134. It is not necessary to perform steps 132 and 132A, because there are no separate PDL and SDL lists for write-once disks.

In the procedure for associating spare sectors with defective sectors (FIG. 9A) step 145 is skipped as there is no SDL list. When the percentage of defective sectors exceeds a desired threshold as found at step 147, a branch is made to the procedure to call for a cleaning process for the disk (FIG. 9B). Once cleaned, excessive use of spare sectors may be halted. The process ends with re-insertion, because defective sectors are not reclaimable in the write-once case.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention.

Claims

1. A method of operating an optical disk drive apparatus including a controller (10) with a microprocessor (15) and working memory (17), comprising setting a threshold of optical disk spare sector consumption and storing the threshold in the

working memory (17), determining spare sector usage and storing the usage in the working memory, and comparing spare sector usage to the threshold, and if the threshold is exceeded, requesting a disk cleaning operation.

2. A method according to claim 1, including, at the time of an initial load into the drive apparatus, formatting all user area sectors on the disk and storing the address of all sectors found defective in a primary defect list (PDL) located on the disk, during subsequent use of the disk, storing the address of all sectors found defective during use in a secondary defect list (SDL) located on the disk, and, after a disk cleaning operation, upon reinsertion of a cleaned disk into the drive, inspecting the SDL and reformatting all sectors therein to determine if they are now reusable.

3. A method according to claim 2, including, for those sectors identified as reusable, reclaiming the reusable sectors by adding them to the available spare sector area.

4. A method according to claim 2, including, for those sectors identified as reusable, reclaiming each reusable sector by writing that data originally intended for it from the assigned spare sector where the data has been located and, if successful, updating the SDL list and adding the assigned spare sector to the available spare sector area.

5. A method according to claim 2, including, for those sectors identified as reusable, reclaiming each reusable sector by restoring them to the user area for further write operations and when successfully written, deleting the sector from the SDL and adding the associated spare sector to the available spare sector area.

6. A method according to claim 2, 3, 4 or 5, wherein the PDL is inspected to identify all sectors in the SDL adjacent to sectors in the PDL, thereupon preparing a modified SDL in working memory in which the adjacent sectors are removed from the SDL, thereupon reformatting all sectors in the modified SDL to determine if they are now reusable.

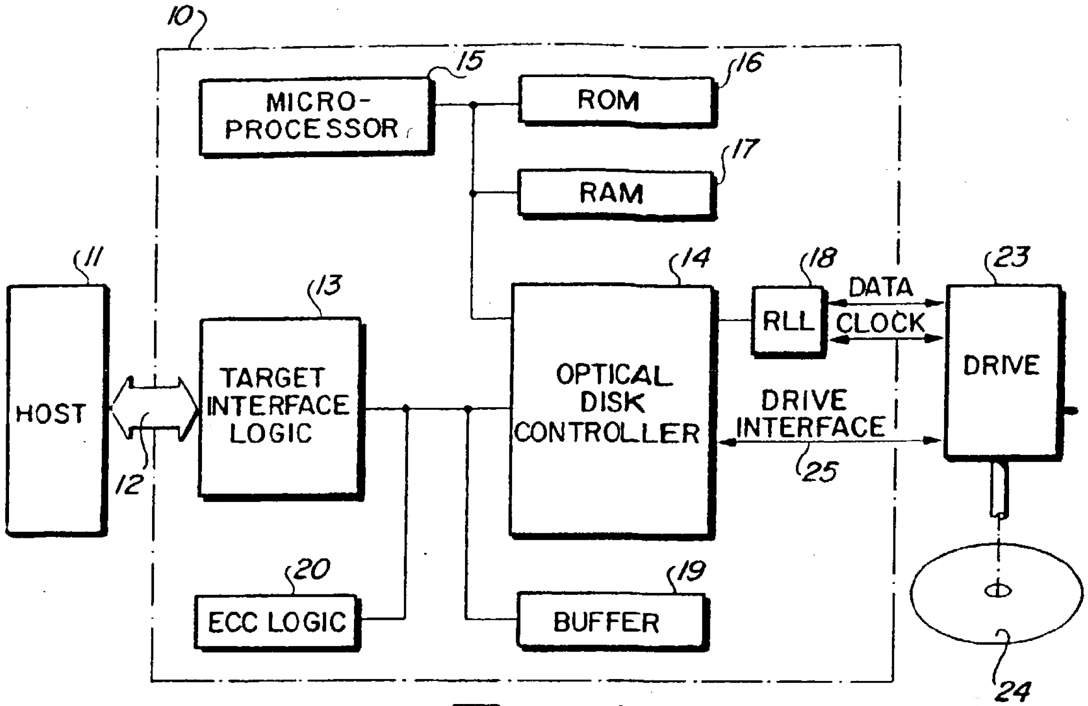
10
15
MICRO-
PROCESSOR
16
ROM
17
RAM
11
HOST
12
13
TARGET
INTERFACE
LOGIC
14
OPTICAL
DISK
CONTROLLER
18
RLL
DATA
CLOCK
DRIVE
INTERFACE
25
23
DRIVE
24
20
ECC LOGIC
19
BUFFER

Fig. 1

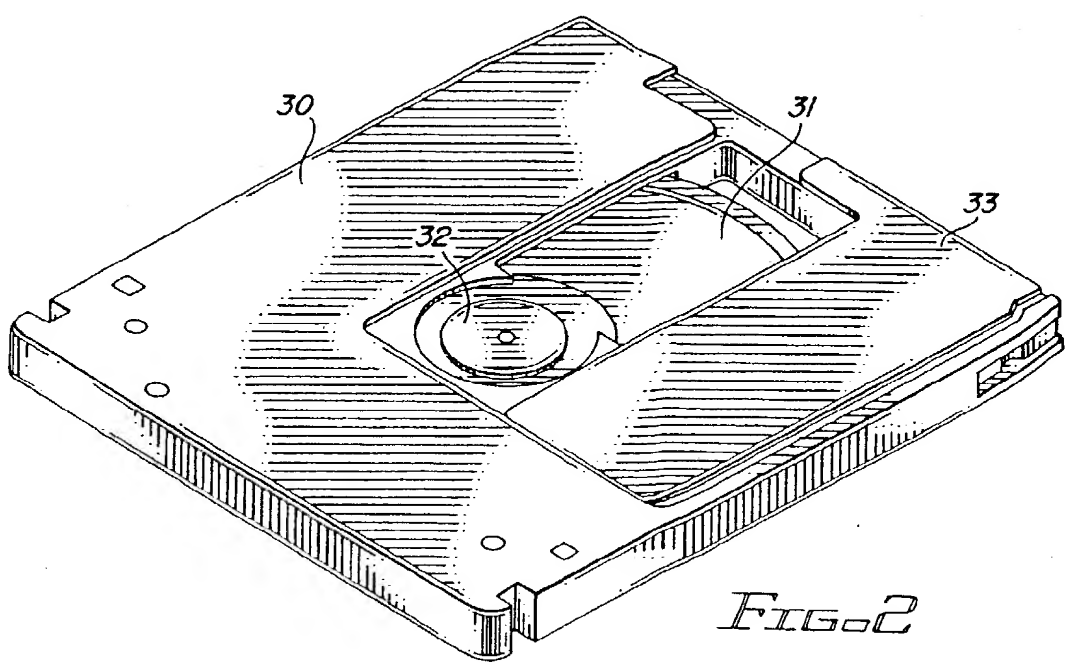
30
31
32
33

Fig. 2

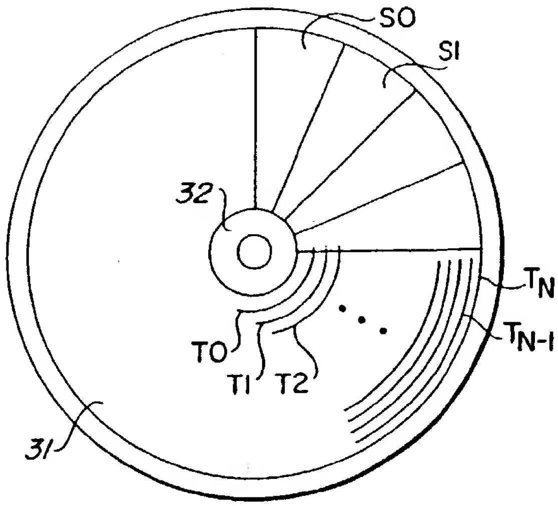

FIG. 3

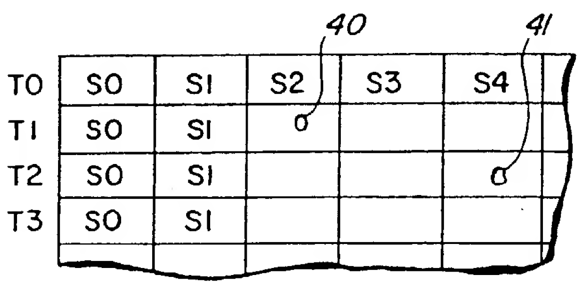

FIG. 4A

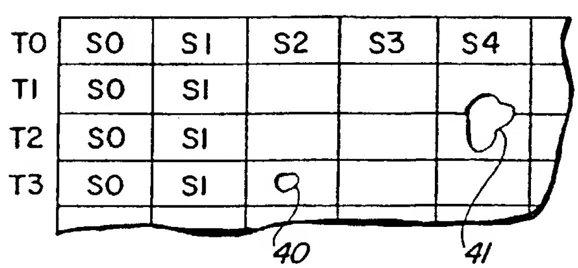

FIG. 4B

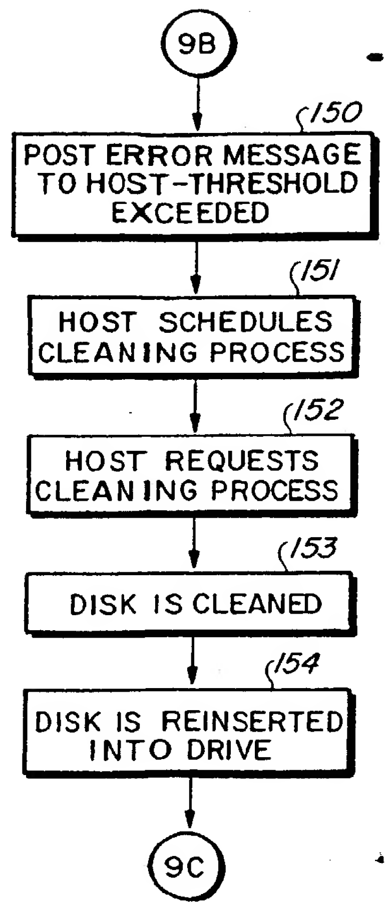

FIG. 9B

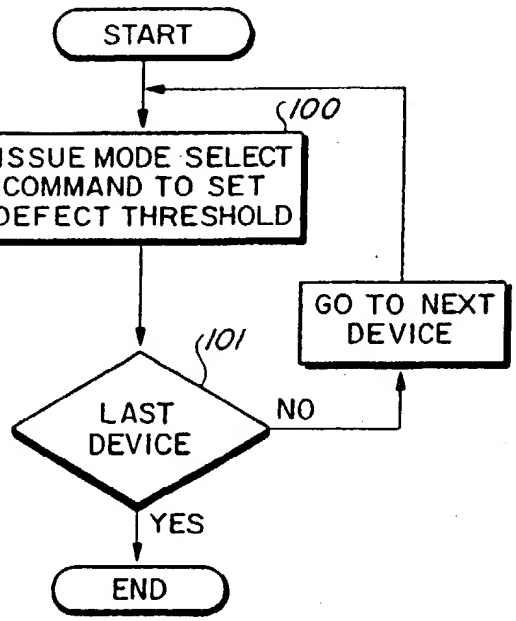
START
100
ISSUE MODE SELECT COMMAND TO SET DEFECT THRESHOLD
GO TO NEXT DEVICE
101
LAST DEVICE
NO
YES
END

FIG. 5

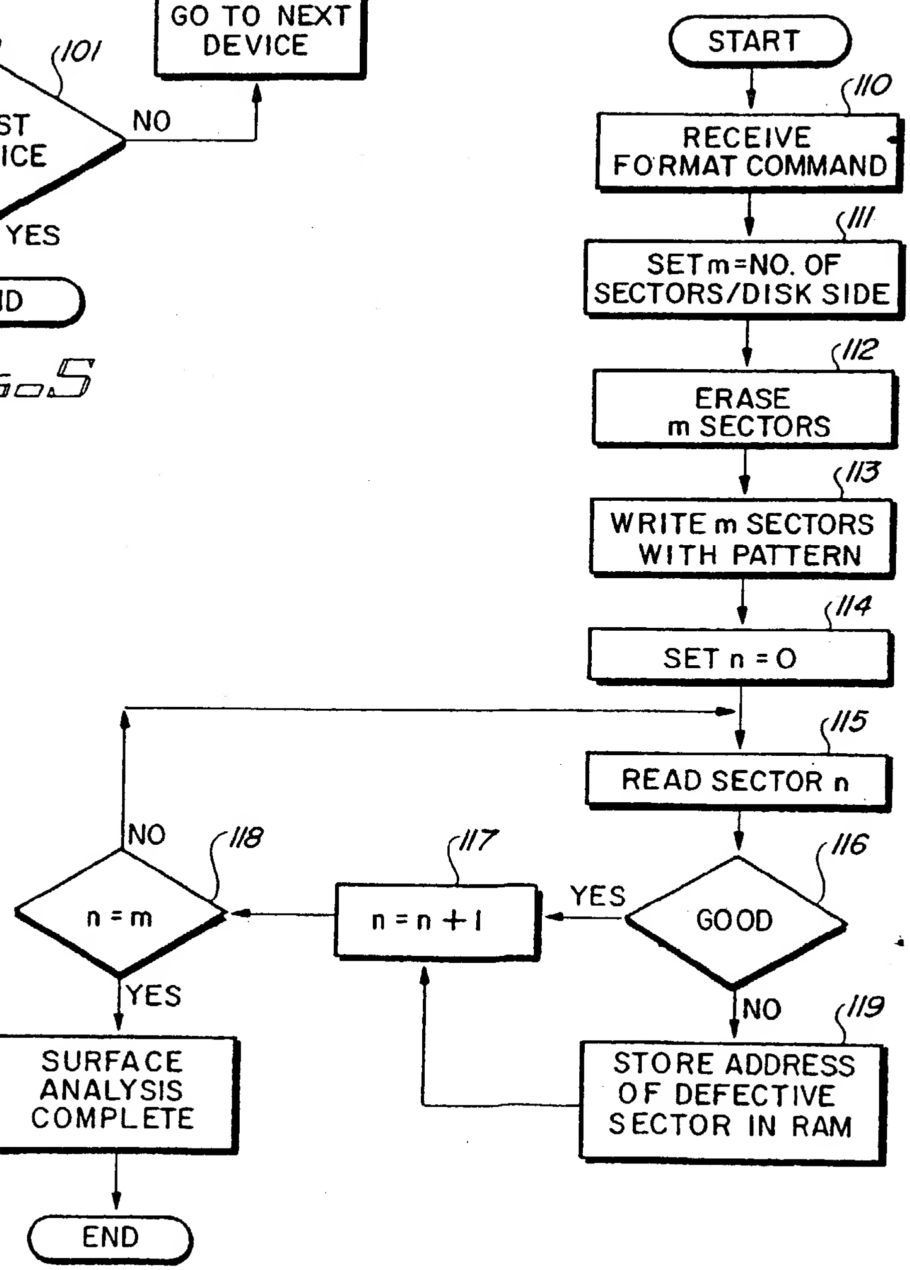
START
110
RECEIVE FORMAT COMMAND
111
SET m = NO. OF SECTORS/DISK SIDE
112
ERASE m SECTORS
113
WRITE m SECTORS WITH PATTERN
114
SET n = 0
115
READ SECTOR n
116
GOOD
YES
117
n = n + 1
118
n = m
NO
YES
NO
119
STORE ADDRESS OF DEFECTIVE SECTOR IN RAM
SURFACE ANALYSIS COMPLETE
END

FIG. 6

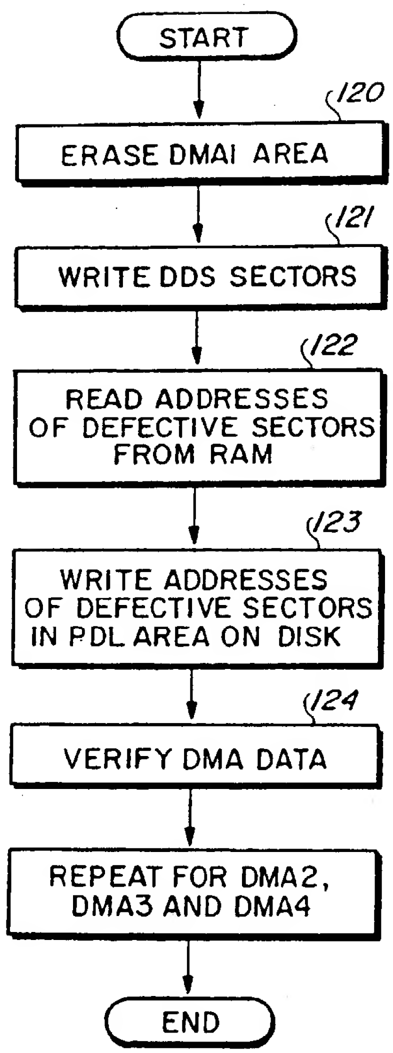
START
120
ERASE DMAI AREA
121
WRITE DDS SECTORS
122
READ ADDRESSES OF DEFECTIVE SECTORS FROM RAM
123
WRITE ADDRESSES OF DEFECTIVE SECTORS IN PDL AREA ON DISK
124
VERIFY DMA DATA
REPEAT FOR DMA2, DMA3 AND DMA4
END

FIG. 7

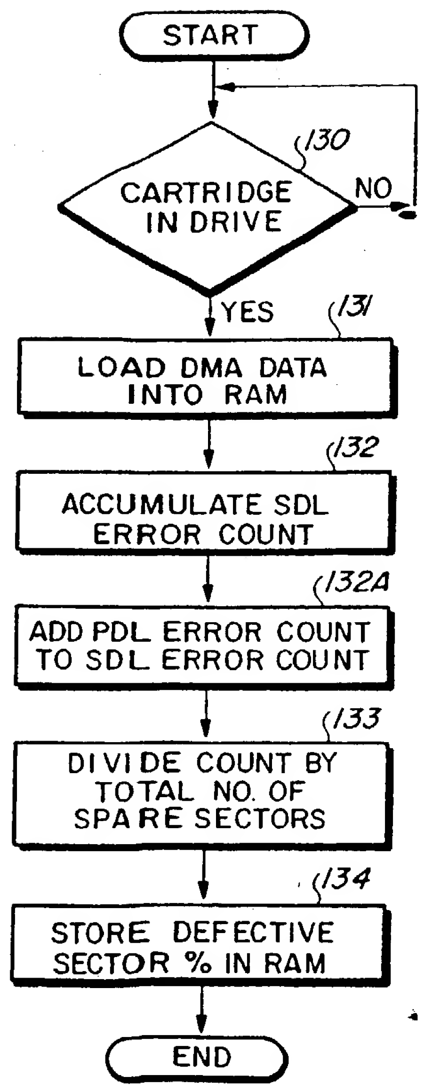
START
130
CARTRIDGE IN DRIVE
NO
YES
131
LOAD DMA DATA INTO RAM
132
ACCUMULATE SDL ERROR COUNT
132A
ADD PDL ERROR COUNT TO SDL ERROR COUNT
133
DIVIDE COUNT BY TOTAL NO. OF SPARE SECTORS
134
STORE DEFECTIVE SECTOR % IN RAM
END

FIG. 8

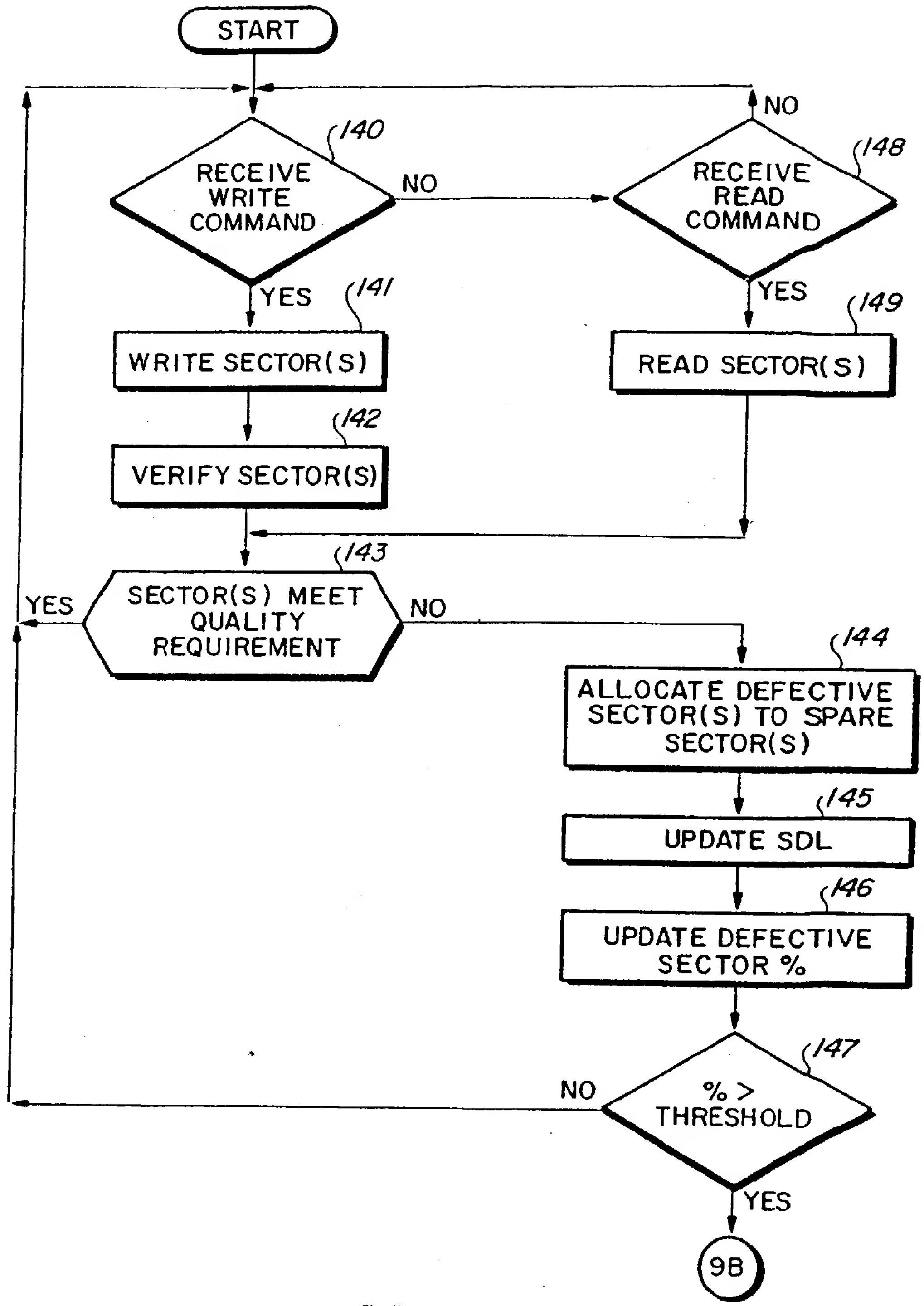
START
RECEIVE WRITE COMMAND
140
NO
RECEIVE READ COMMAND
148
NO
YES
141
WRITE SECTOR(S)
YES
149
READ SECTOR(S)
142
VERIFY SECTOR(S)
143
YES
SECTOR(S) MEET QUALITY REQUIREMENT
NO
144
ALLOCATE DEFECTIVE SECTOR(S) TO SPARE SECTOR(S)
145
UPDATE SDL
146
UPDATE DEFECTIVE SECTOR %
147
NO
% > THRESHOLD
YES
9B

FIG. 9A

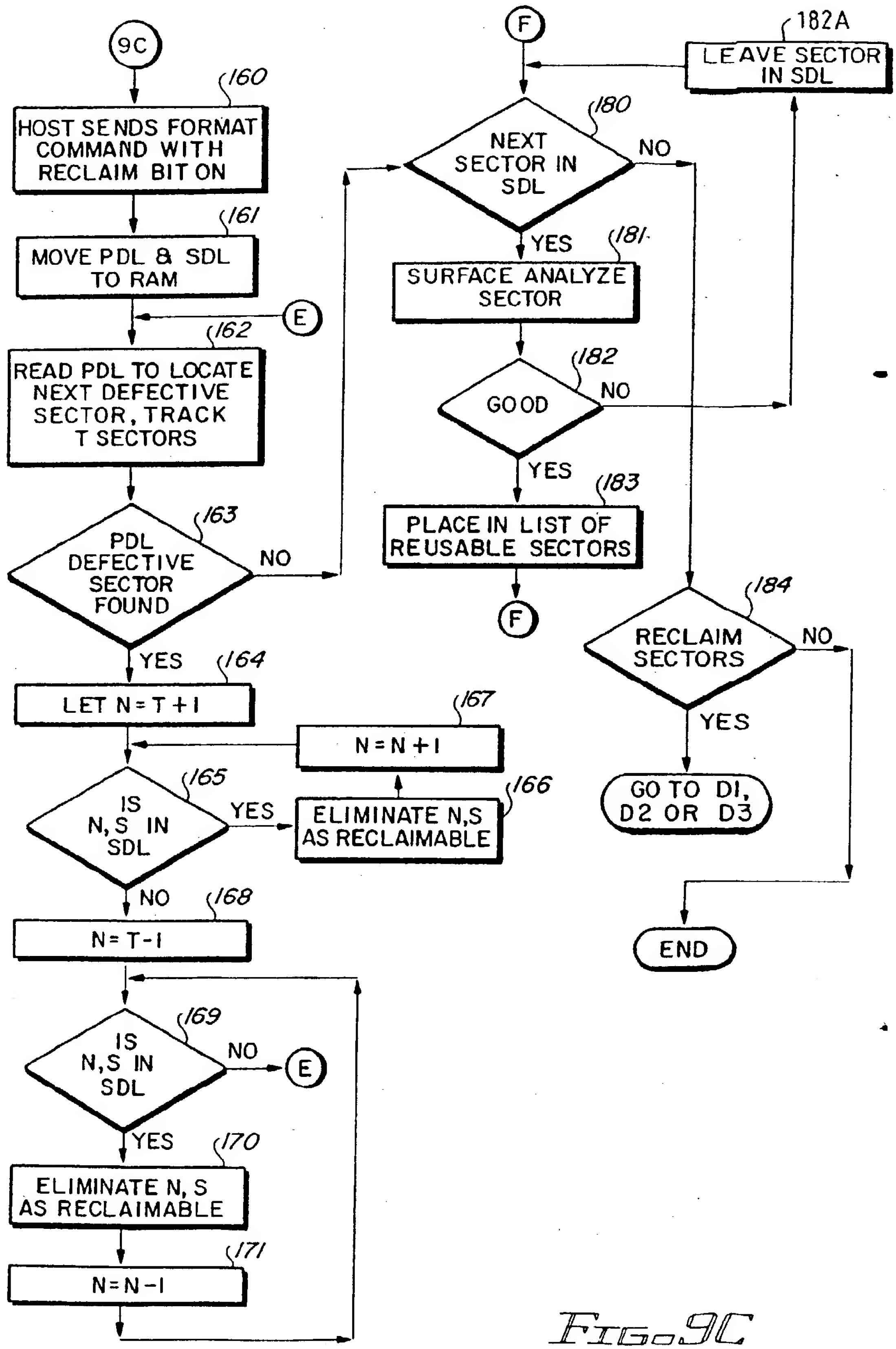
9C
160
HOST SENDS FORMAT COMMAND WITH RECLAIM BIT ON
161
MOVE PDL & SDL TO RAM
E
162
READ PDL TO LOCATE NEXT DEFECTIVE SECTOR, TRACK T SECTORS
163
PDL DEFECTIVE SECTOR FOUND
NO
YES
164
LET N=T+1
167
N=N+1
165
IS N,S IN SDL
YES
166
ELIMINATE N,S AS RECLAIMABLE
NO
168
N=T-1
169
IS N,S IN SDL
NO
E
YES
170
ELIMINATE N, S AS RECLAIMABLE
171
N=N-1
F
182A
LEAVE SECTOR IN SDL
180
NEXT SECTOR IN SDL
NO
YES
181
SURFACE ANALYZE SECTOR
182
GOOD
NO
YES
183
PLACE IN LIST OF REUSABLE SECTORS
F
184
RECLAIM SECTORS
NO
YES
GO TO D1, D2 OR D3
END

FIG. 9C

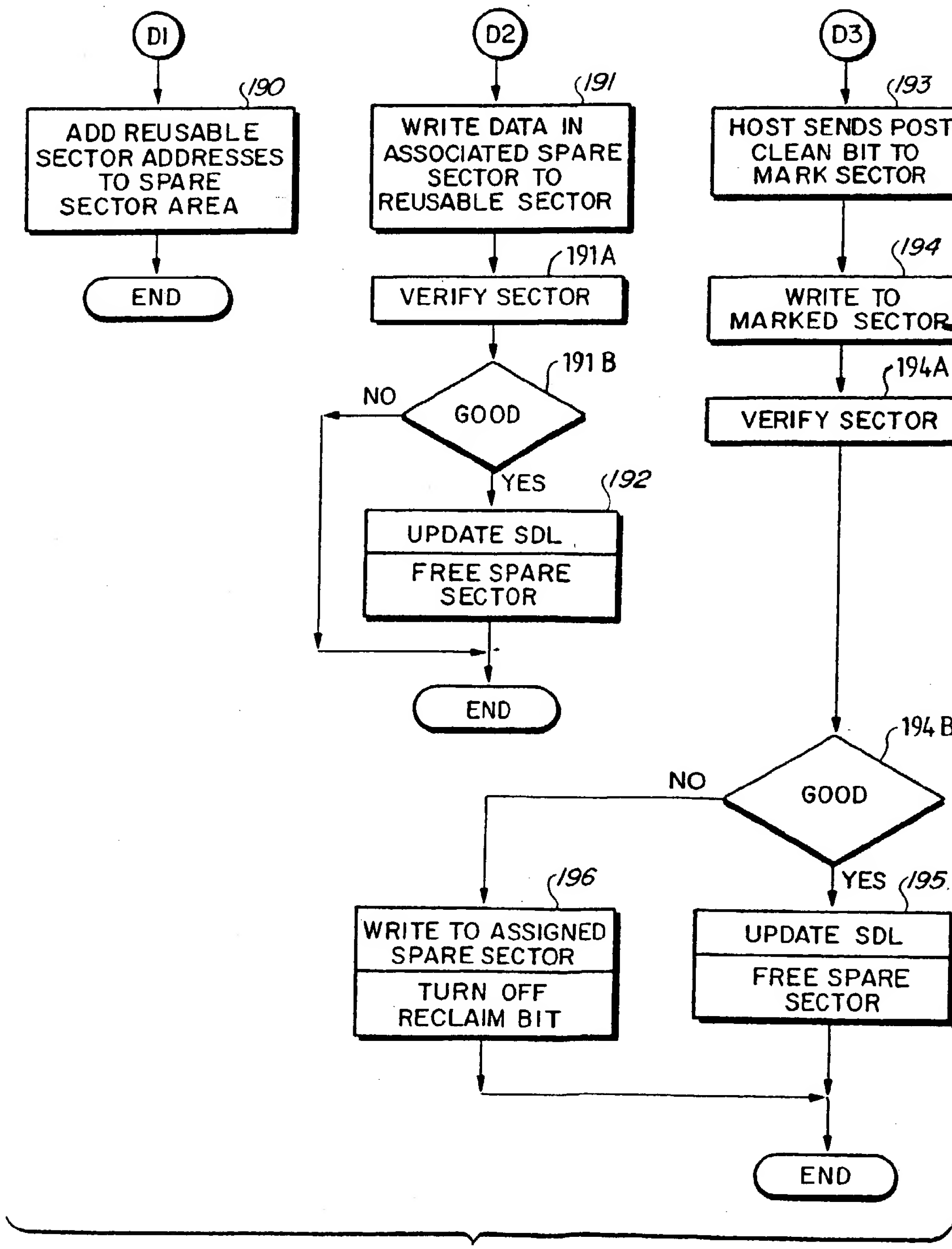
D1
190
ADD REUSABLE SECTOR ADDRESSES TO SPARE SECTOR AREA
END
D2
191
WRITE DATA IN ASSOCIATED SPARE SECTOR TO REUSABLE SECTOR
191A
VERIFY SECTOR
191 B
GOOD
NO
YES
192
UPDATE SDL
FREE SPARE SECTOR
END
D3
193
HOST SENDS POST CLEAN BIT TO MARK SECTOR
194
WRITE TO MARKED SECTOR
194A
VERIFY SECTOR
194 B
GOOD
NO
YES
195
196
WRITE TO ASSIGNED SPARE SECTOR
TURN OFF RECLAIM BIT
UPDATE SDL
FREE SPARE SECTOR
END

FIG. 9D

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 30 8083

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 32, no. 6A, November 1989, NEW YORK US pages 319 - 324 'ERASE DETECTION AND ERROR RECOVERY FOR OPTICAL FILES' * the whole document *	1	G11B20/12 G11B20/18 G11B27/36
A	EP-A-0 357 049 (MATSUSHITA ELECTRIC INDUSTRIAL CO.) * page 4, line 53 - page 7, line 15 *	1-2	
A	EP-A-0 350 920 (MATSUSHITA ELECTRIC INDUSTRIAL CO.) * page 8, line 3 - page 14, line 24 *	1-2	
A	US-A-4 363 117 (C.WINE) * the whole document *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G11B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 JANUARY 1993	KELPERIS K.

CATEGORY OF CITED DOCUMENTS

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